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AFFORDABLE WATER SUPPLY AND SANITATION

Disseminating ram-pump technology

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FOR BOTH IRRIGATION and domestic supply, gravity feed is not always possible: water often needs lifting. The power to lift a flow of water can conveniently be expressed as

$$\text{power} = \frac{\text{constant x mean flowrate x height lifted}}{\text{duty x efficiency}}$$

where 'duty' is a time fraction (pumping hours per day) and 'efficiency' is a product of the efficiencies of the hydraulic circuit, the pump and the prime mover. Pipes are sized to give tolerable hydraulic efficiency and pumps are chosen to match the hydraulic conditions and the energy source available. Duty can also be varied to achieve better matching of the prime mover to the hydraulic circuit: high duties such as continuous 24-hour operation result in low power requirements and cheap piping (see Box on next page).

Whilst in general the power for water-lifting can come from engines, electrical mains, animals, humans or renewable (climatic) sources, in the particular context of rural areas in poor countries the choice is more constrained. In many such countries there are virtually no rural electrical mains, engines pose problems of both fuelling and maintenance, draught animals may be unavailable or difficult to apply to water lifting, renewables are erratic, complex and import intensive. Therefore human-powered lifting and transporting of water is still common, despite the very high cost of human energy (US$ 2 to 20 per kW hour).

Of the renewables, water power has the longest history, and under favourable conditions is the easiest to use. Several Asian and Latin American countries have developed the capability of building hydro-power systems. Although sites where power can be economically extracted from falling water are rather rare, they generally occur in the same terrain (mountainous) as the greatest water-lifting needs. The use of water power to pump water is therefore an interesting option. Figure 1 shows the main ways of doing this and illustrates the relative simplicity of the hydraulic ram-pump system. A typical such system is shown in Figure 2.

Ram-pumps (invented 200 years ago) are still manufactured in over ten countries and were once commonplace in Europe, The Americas, Africa and some parts of Asia. They have however been largely displaced by motorised pumping in richer countries, whilst in developing countries their use is concentrated in China, Nepal and Colombia. Ram-pump technology is not trivial: designing systems that are reliable, economic and durable (e.g. against flood, theft, silt ....) takes some experience. Generally, in rural areas of developing countries, this skill has been lost since about 1950, and the intermediaries that used to connect ram-pump manufacturers to pump users have disappeared. Old systems lie broken for lack of fairly simple maintenance: new systems are few.

Figure 1. Different configurations for water powered pumping.

For various reasons, discussed later, the potential for using ram-pumps seems to be increasing worldwide. Working, primarily in Africa, since 1985 the Development Technology Unit of Warwick University has identified several obstacles to this potential being realised, and has been trying to remove them. This paper records that experience.

The niche of the ram-pump

In suitable terrain, ram-pumps can be used to provide low-power unsupervised pumping. Typical individual ram-pumps can deliver 10 to 200 watts for lifting water; several small pumps can be operated in parallel to feed a single delivery pipe, larger pumps are available from some manufacturers. The power requirements of rural water lifting are illustrated by the following examples, which all assume pipe head losses are 10% of lift. The powers quoted are 'water watts' assuming 24 hours pumping.

domestic supply to a prosperous house (500 litres per day lifted 75m)	5W
village supply (l0,000 litres per day lifted 50m)	62W
irrigated garden (0.5 hectare) (35,000 litres per day lifted 20m)	87W

As the ram pump's system efficiency including its drive pipe is 50% to 75%, the hydro-power inputs for the examples above need to be up to twice the figures shown. The ram-pump is therefore well power-matched to these applications. These inputs are obtained at comparatively low drive heads - typically 10% of the delivery head - so the drive flows to ram-pumps are typically twenty times their delivery flows. (In the examples above the drive flow would be typically 7, 140 and 500 litres per minute respectively). This high flow requirement is clearly a constraint on location. On the positive side, however, no ram-pump user can extract more than a small fraction (e..g. 5%) of any source flow, the bulk of it being passed on downstream to other users: this has some social advantages.

Three other technical constraints require mention. Firstly there is only a limited range of head ratios (delivery height divided by drive head) of 5 to 30 over which a ram-pump is efficient and economic. Secondly neither drive head nor delivery head should exceed the particular pump's rating (often 20m and 100m respectively, but much less for cheap plastic ram-pumps). Thirdly it must be acceptable that the water lifted is derived from - and hence is of the same quality as - the drive water: a ram-pump cannot derive energy from a dirty stream to pump water from a different (cleaner) source.

Disregarding social and organisational factors, we can therefore describe the technical niche of the ram-pump as moist hilly rural areas where there is no mains electricity but a need for lifting water from streams or springs. The source must be of adequate quality and have a flow many times that to be lifted.

Figure 2. Typical ram pump system.

The problem of minor technologies

One of the more accessible concepts from 20th Century physics has been that of 'critical mass'. If the mass of a radioactive material or the size of an organisation is below some threshold its activity dies away; above that threshold the activity sustains itself and may even grow. For most technologies there is similarly a critical scale of application below which the activities needed to sustain it may die away. Such activities include manufacture of components, training of new users and specialist maintenance.

In the case of ram-pump systems, specific skills are needed in manufacture, system design, installation and operation. The skills are not especially high and overlap those needed to manufacture, install etc. other devices. Sometimes such skills are preserved in inanimate form. Thus many ram-pump manufacturers employ steel castings whose foundry patterns were made decades ago. Documents preserve design procedures. Existing installations are available as models for new systems. The critical throughput to sustain commercial manufacture is perhaps 50 pumps per year, it is usually achieved via selling into more than one country. A throughput of only one or two new systems a year might sustain system design and installation skills in a general water contractor. However, a specialist installer might need to put in at least 20 pumps a year to survive.

Box Continuous pumping versus discontinuous pumping

Water and wind powered pumps, and some electric pumps, are best operated for 24 hours per day. Solar, human and animal-powered pumps are limited to about 8 hours per day. Diesel pumps are typically run for only 2 hours per day in rural areas because they are usually over-powered for their applications. These differences in duty (load factor) have implications for pipe and storage costs. Pipes are sized so as to give a 'tolerable' friction head loss (FHL). What is tolerable depends on the means available to supply this head loss, for example pump power or the slope of the pipe. We know that, for a given length of pipe, FHL is proportional to Q^2/D^5, where Q is flowrate in the pipe and D is its diameter. Also pipe cost (per meter) is typically proportional to D^2. These relationships give the table below, which is based on a specified daily flow.

	Pumping for 24 hours/day (taken as datum)	Pumping for 1 x 8hrs/day	Pumping for 2 x 1 hr/day = 2hrs/day
Power to overcome FHL	1	x27	x1728
Energy to overcome FHL	1	x9	x144
Pipe D for constant FHL	1	x1.5	x2.7
Pipe cost for constant FHL	1	x2.4	x7.3
Typical storage ÷ daily throughput	0.4	0.5	0.4

In reviving an old technology or introducing a new one, the 'critical mass' throughputs need to be estimated. If they are higher than the area of sales or of installer operation can sustain, any intervention to promote the technology will ultimately fail. More important, if the likely demand is thought to be close to such a threshold of sustainability it is worth effort to lower the threshold.

With the technology of hydro-electricity we are used to having separate organisations making turbines, designing systems, building them and operating them. Maintenance may require a fifth agency. Even though some of these organisations operate internationally via local agents, such complexity entails uncertainties that tend to raise the critical size for each of them. Micro-hydropower utilisation has lagged behind its apparent economic potential for these reasons in most countries. Ram-pumping faces similar difficulties.

Often there is a key agency that effectively leads the others involved in a technology. For example a manufacturer of equipment may set up training for its installers, users and maintainers; alternatively a consultant may co-ordinate and supplement the existing skills of the other parties. A low value rural technology does not lend itself to the latter approach.

Experiences in Africa

The author and his DTU colleagues have been trying to revive ram-pump usage in Africa since 1985. An early analysis suggested that foreign (e.g. European) manufacturers selling a few pumps a year via agents could not and would not provide adequate training for local installers. Moreover imported pumps are expensive and difficult to source spares for. In colonial times there were few technical alternatives for water lifting to plantations, mission hospitals and large schools and it was worth the cost of bringing a ram-pump installer from another continent. Today that is an unacceptably expensive option for a village or farm needing pumped water or for a small-scale pumped irrigation scheme.

In the absence of a design consultant (again unlikely for this scenario), the options for sustainability appeared to be

either to build up the design capability of installation contractors

and/or to encourage local manufacture by an organisation also capable of providing back-up to installers.

The DTU chose the 'and' option, first spending several years in developing simple and cheap pump designs suitable for provincial manufacture and codifying system design and installation procedures. Since 1990 the DTU has been training both producers and installers from nine African and one Asian country, usually using its demonstration centre in the Eastern Highlands of Zimbabwe. There is an ongoing debate about what is the right level of manufacturing technology (hand tool, workshop with electricity, factory), whether manufacture and installation should be undertaken by the same organisation, whether low-lift irrigation or high-lift water supply should be given priority, whether installer training should be directed towards governmental, NGO or private organisations and what fraction of possible sites are 'easy' sites suitable for beginners to tackle.

The results have been mixed. Easy sites (with modest lifts, plentiful water, favourable stream geometry and well-organised customers) are perhaps only a few percent of technically feasible sites. The process of system design has proved intimidating to technicians for whom even sizing a pipe for gravity flow is at the limit of their understanding. The input of (expatriate) man and woman power to bring an installation organisation up to the level of competence and confidence to stand alone with this technology has been expensively high. The 'successes' have been with unusually well-resourced NGOs. Commercial manufacture, for example in Kinshasa (Zaire) and Mutare (Zimbabwe) has been started but self-sustaining manufacturer-installer arrangements have not been developed. Of some 30 pumps installed, too many have been 'demonstrations' rather than built to meet real water needs.

Clearly training on courses alone is not enough. Installers and manufacturers need to be visited and helped / encouraged with production of their first systems. A ram-pump has a certain 'something-for-nothing' magic about it that impresses onlookers and causes any installation to yield many enquiries from neighbouring villages or farms. However the technology's uncertainties, using very cheaply produced pumps in the hands of novice installers, makes it much easier to apply to individual 'rich' farms or institutions than to villages or communal dry-season gardens.

Ram-pump technology has a fascination for enginers and users out of proportion to its current commercial importance. The DTU's 1992 book on system design must have sold more copies worldwide than there have been new systems built! A 1993 day school on ram-pumps in Sri Lanka attracted fifty engineers but so far has resulted in no new systems.

Prospects

Ram-pumping will never be a major technology comparable with motorised pumping from rivers or hand pumping from boreholes. Its particular niche is described above: worldwide there is a potential for between perhaps 10,000 and 200,000 systems. Much of that potential lies in areas where there are currently no system design skills. Availability of pumps need not be a major problem (despite the DTU's local manufacture strategy in Africa), since even though good imported machines cost over $10,000 per kilowatt the pump itself rarely accounts for more than 40% of system costs.

Certain trends worsen the prospects for ram-pumps. Worldwide, water sources are becoming both dirtier and weaker. Some historical ram-pump systems no longer operate because of declining drive flow. Clean spring water is usually associated with very low power levels - in Rwanda for example, the DTU had to design for 80 metre lifts from drive flows under 10 litres per minute, which is on the limits of the technology.

Factors increasing likely demand are the movement of rural populations uphill (under population growth pressures), the expansion in micro-irrigation, the introduction of local ram-pump manufacture (especially in S. America) and the availability, apparently for the first time in decades, of both trustable handbooks and training courses.

In Africa the prospects for ram-pump usage seem to depend largely on the confidence of potential installers. Despite much individual innovation there, Africa is not a continent where organisations readily take risks with unknown technology. Elsewhere in the developing world continuation of the current slow expansion of ram-pump usage will depend upon developments in photo-voltaic pumping, its most immediate rival.

The scope for technical improvement of a simple device already used for 200 years is rather small. However, modern materials may permit the pressure vessel (required to smooth the pulsating flow through the delivery valve into a steady flow up the delivery pipe) to be replaced by a pressured bladder. This will allow pumps to be operated slightly under water which has advantages for both efficiency and reliability. Understanding of the causes of erratic pump behavious and of inefficiency is now better than in the past, which designers of pumps and 'trouble-shooters' of systems can draw upon. It is not possible to totally design away temperamental behaviour, during for example system start-up, but its incidence can certainly be reduced.

For the ram-pump to fully occupy its niche, efforts must continue both to simplify the design of reliable systems and to propogate design skills. Although water-powered pumping will never attain the simplicity of "drop the suction pipe in the stream and switch on" that motorised pumping offers, as users of a renewable energy source, ram-pumps may have time on their side.

References

The following books explain how ram-pumps work and provide system design assistance. They also contain addresses of (Northern) manufacturers.

Meier V. *Hydram Information Package*, SKAT, St. Gallen, 1990.

Knol H. *The Fall and Rise of the Hydraulic Ram-pump*, Drachten (Netherlands), 1991.

Jeffery T. et al *The Hydraulic Ram-pump*, London, IT Pubs, 1992.

Please contact the DTU, Warwick University, Coventry, CV4 7AL, UK for drawings of pumps designed for local fabrication.